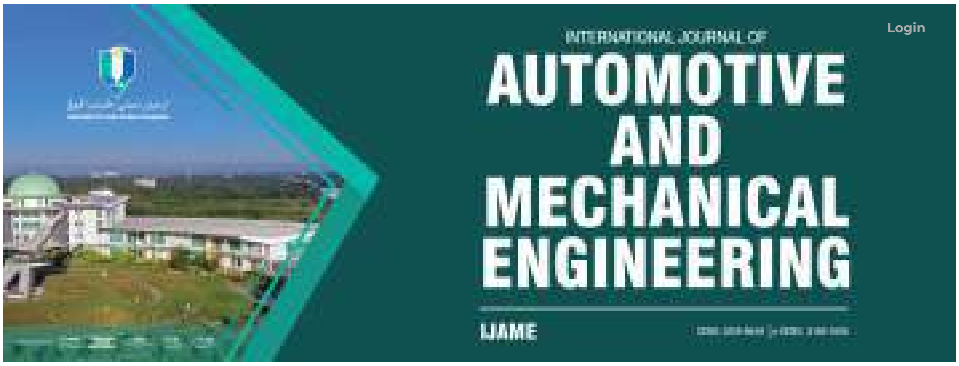

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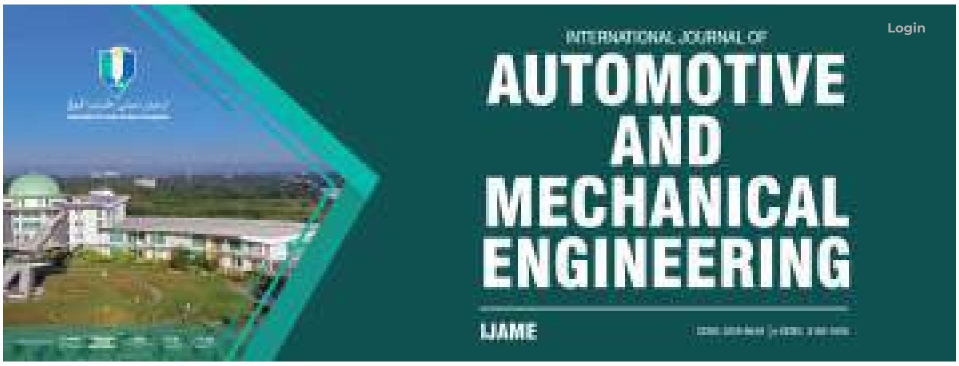

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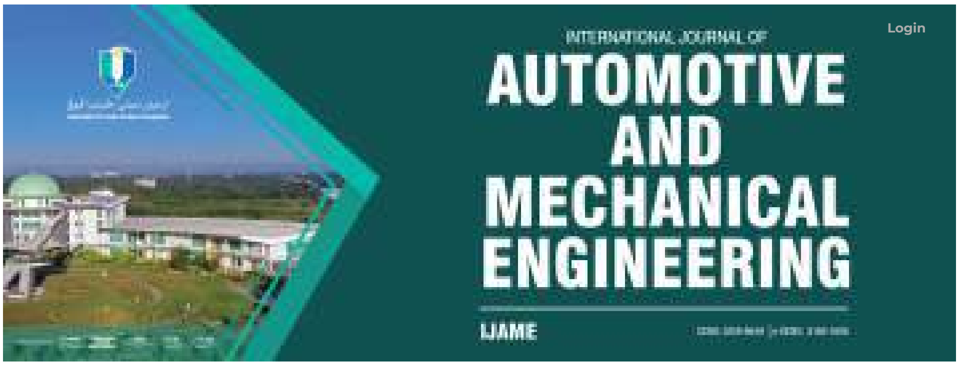

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ORIGINAL ARTICLE

Machinability Study in Turning of Ti-6Al-4V under CO_2-based Vortex Tube Cooling System

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ABSTRACT – The study on the machinability of titanium alloys provides new ways to minimize the difficulty levels of machining the alloys due to substantial heat accumulation. To improve machinability, pivotal factors such as heat accumulation and cutting temperature must be regulated. In this study, a turning operation was performed on Ti-6Al-4V and the cutting temperature was reduced by supplying cooled CO_2 gas through a vortex tube connected with two nozzles. Variations in cutting force, cutting temperature, and surface roughness with cutting speed, feed, and depth of cut were recorded. Subsequently, responses were compared for single nozzle vortex tube, dry, and compressed air environments at different cutting speeds. Cutting force and surface roughness followed a similar trend which increased with decreasing speed, and increasing feed and depth of cut. The cutting temperature increased with all three variables. The proposed cooling system provided better results in terms of cutting temperature and surface roughness, while a marginally higher cutting force was observed compared to dry cutting.

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INTRODUCTION

The alloys of titanium are widely used in the aerospace industry because of their lightweight and retaining strength at high temperatures, in the marine industry because of their resistance against corrosion and erosion in seawater, and in the automobile industry due to their specific strength. Ti-6Al-4V is a highly popular alloy of titanium because of its properties like high specific strength and corrosion resistance. Machining Ti6-Al-4V is difficult because of its low thermal conductivity and high strength. Controlling cutting temperature in Ti-6Al-4V machining is a major challenge faced by industries because of high heat generation. Cutting fluids have been used for this purpose from the beginning, but their use needs to be minimized because of drawbacks like environmental pollution and hazards for human and aqua life. To overcome these problems, different cooling approaches have been developed as a substitute for cutting fluids, such as dry cutting, near dry cutting, pressurized air cooling, and cryogenic cooling like LN2 (liquid nitrogen) [1].

Arauzo et al. [2] used a vapor compression refrigeration system to supply cool compressed air in SAE 1045 steel machining, and better tool life and surface roughness were observed compared to dry conditions. Sartori et al. [3] used CO_2 and LN2 as coolants in MQL in Ti-6Al-4V machining and found higher tool life in using CO_2 gas. Sadik et al.[4] used liquid CO_2 gas in the face milling of Ti alloy and compared the responses with wet conditions. CO_2 gas cooling provided better tool life, and it enhanced with an increase in gas flow rate. Dong-Won Kim et al. [5] used cryogenic LN2 as a coolant and compared the responses with traditional coolants in titanium machining. A reduction of 54% in cutting force and an improvement of tool life by 90% was recorded with cryogenic LN2. Suarez et al. [6] used high-pressure coolants in turning IN718 and found that this method reduced the cutting force and flank wear, whereas marginally higher notch wear was obtained compared to conventional cooling.

Sartori et al. [7] used nitrogen gas as a coolant in the range of 0 °C to -150 °C in Ti-6Al-4V machining. It was found that nitrogen at -150 °C performed better compared to LN2 and wet cooling in terms of surface finish and tool wear. Shokrani et al. [8] used LN2 in the milling of Ti-6Al-4V and compared the responses with flood conditions. Improvement in tool life by three times and reduction in surface roughness by 40% was achieved with LN2. Christian Machai et al.[9] used CO_2 snow as a coolant in turning Ti-10V-2Fe-3Al and found that tool life doubled using this coolant compared to flood emulsion. Burr formation and notch wear were also reduced significantly in the process. Gonzalez et al. developed a new method to inject CO_2 gas with MQL in the machining of integral blade rotors (IBRs) made of Ti-6Al-4V to prevent the formation of dry ice [10]. Salaam et al. [11] used a vortex tube to supply chilled air as a coolant in turning mild steel. Surface quality improved, and cutting temperature was reduced with vortex tube cooling compared to ambient conditions. The use of CO_2 leads to environmental neutrality through the use of gas obtained as a waste product in industrial and chemical processes [12].

Gupta et al. [13] used dry, N_2 cooling, N_2MQL, and RHVT-N_2MQL cooling environment in Al 7075-T6 turning. RHVT-N_2MQL provided improved surface quality and tool life compared to other conditions. Rahman Rashid et al. [14] machined Ti-6Cr-5Mo-5V-4Al by attaching it to a laser source. It was seen that lower cutting force and higher metal removal rate were achieved by this technique compared with conventional methods. Rotella et al. [15] analyzed the microstructure, grain refinement, and surface quality under dry, MQL, and cryogenic environments at various speeds, *v*,

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ORIGINAL ARTICLE

Parametric Analysis of a Divided Rocker for Battery Electric Vehicles

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ABSTRACT – The driving range of an electric vehicle can be increased through an efficient integration of the large battery within the vehicle structure. In this regard, a divided rocker concept from an existing study is investigated, in which the vehicle rocker is divided into two parts by means of a division plane. One part of the rocker remains vehicle sided and enables the attachment of the surrounding vehicle structures, while the other part is functionally integrated into the side frame of the battery housing. In the scope of this paper, several division plane concepts for such a divided rocker are created and analyzed. The crash performance of the modelled division plane concepts is studied on a component level using the side pole crash test as a load case. For the different division planes, a parametric analysis is performed by varying the number of chambers in the rocker profile, the chamber width, mass distribution, individual section thicknesses, the height of the division planes, and the air gap between the vertical surfaces of the division planes. Several crash performance criteria, such as structural deformation, force, and energy absorption, are examined. Among the studied parameters, the number of chambers and mass distribution have notable influences, while individual section thicknesses and the height of the division planes do not have a significant influence on the crash performance. Lastly, stiffer chambers in the battery-sided rocker created by decreasing the chamber width have the strongest effect on crash performance.

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INTRODUCTION

Amid growing concerns about climate change and rising global temperature, governments and regulatory bodies are introducing laws and policies to reduce CO_2 emissions and shift towards renewable energy sources. In this regard, the European Union has put forward a plan to cut CO_2 emissions by at least 55% below 1990 levels by 2030 [1]. The United States government has also set a target for reaching net-zero greenhouse gas emissions by 2050 [2]. To meet tighter emission restrictions and targets set by governments, automotive manufacturers are focusing on battery electric vehicles, among other alternatives [3]. As the driving range is one of the major customer concerns regarding Battery Electric Vehicles (BEVs), large batteries are integrated within the vehicle structure to achieve a similar driving range as conventional Internal Combustion Engine (ICE) vehicles [4]. The battery of modern electric vehicles is located below the vehicle floor, as indicated in Table 1.

Table 1. Overview of recent electric vehicle batteries [7], [8]

Car Model	Battery (*kWh*)	Cell Type	Location
VW I.D.4	82.0	Pouch	Floor
Ford Mustang Mach-E	98.7	Pouch	Floor
Hyundai Ioniq 5	72.6	Pouch	Floor
Tesla Model S	95.0	Cylindrical	Floor
Mercedes-Benz EQS	120.0	Pouch	Floor
Porsche Taycan	93.4	Pouch	Floor
BMW iX	111.5	Prismatic	Floor
Polestar 2	78.0	Pouch	Floor
Audi Q4 e-tron	82.0	Pouch	Floor

The benefits of the battery location within the area of the vehicle floor include increased torsional stiffness for the vehicle body and low centre-of-gravity of the vehicle. However, the placement of the battery below the vehicle floor poses a challenge regarding crash safety [5]. Incidents of fire during and after a crash and recalls of electric vehicles by manufacturers over battery fire concerns indicate the need for the safe integration of the battery within the vehicle

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